Hot electrons and hard X-rays generation in the intense laser interaction with metal targets

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Knowledge about the laser energy coupling into the energy of accelerated relativistic electrons is of paramount importance for understanding of a short pulse laser – matter interaction. Experiments at the GSI with high intensity laser system PHELIX have been aimed on the investigation of generation of the 22.1 keV Ag *Kα* radiation for radiographic applications.

Silver blocks of 3 mm thickness and silver foils of 10 and 100-µm thickness, attached onto aluminum or plexiglass substrates, were used as the targets. The substrates were employed to investigate influence of a bulk substrate, both conducting and nonconducting, on the process of hot electron refluxing in thin foils. The PHELIX laser pulses with wavelength of 1.053 *µ*m, energy of 80−115 J, average duration of 0.78 ps and nanosecond ASE contrast of 10–6 were focused onto the Ag targets under an angle of 10° to the target normal. The laser intensity was varied in the range between 2 × 1019 W/cm2 and 1018 W/cm2 by displacement of the target out of the best focus. The total error of the laser intensity determination has been estimated as ±20%.

We have developed a model of characteristic [1, 2] and bremsstrahlung X-rays generation by laser produced relativistic electrons propagating in a metal target. The model takes into consideration energy losses of the electrons, cross-sections of the X-rays generation, as well as an absorption of the X-rays. We have applied this model to reveal an intensity dependence of conversion efficiency of laser energy into hot electrons using measurements of absolute *Kα* yield from the silver targets. We have analyzed intensity dependence of hot electron temperature using bremsstrahlung measurements by the radiation attenuation method [3].

We have determined the conversion efficiency in the intensity range under consideration taking into account the *Kα* yield per unit laser energy. We consider two intensity dependencies of the hot electron temperature: the ponderomotive scaling by Wilks *et al.* and the empirical scaling by Beg *et al*. In both cases, the intensity dependences of the *Kα* yield, calculated with the assumption of suppression of hot electron refluxing, describe well features revealed in the experiment. The calculations with refluxing electrons confirm the assumption about suppression of hot electron refluxing in the foils deposited on bulk substrates, both conducting and nonconducting.

Modeling of a spectrum of hard bremsstrahlung X-rays from a bulk silver target and calculation of a detector response after transmission of this radiation through lead filters and Teflon sheets show good agreement with the measurement with 3 mm Ag block at the intensity of 1.6 × 1018 W/cm2, at which both scaling lead to close values of hot electron temperature. Similar modeling and comparison with the measurement at the intensity of 2 × 1019 W/cm2 reveal correspondence of the hot electron temperature with the Beg scaling.

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References

1. A.V. Ovchinnikov, O.F. Kostenko, O.V. Chefonov, *et al.*, Laser Part. Beams **29**, 249 (2011).
2. O.F. Kostenko, N.E. Andreev, Quantum Electron. **43,** 237 (2013).
3. O.F. Kostenko, N.E. Andreev, O.N. Rosmej, A. Schönlein, Phys. Plasmas (submitted).